Development of Productive Uses of Energy in electrification interventions

Research Project ERM *Final version, October-2015*

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I would like to thank Bart-Jan van Beuzekom and other EnDev Nepal staff for their support in the initial stage of the research when it was still focused on improved water mill electrification in Nepal. I would also like to thank all other GIZ Nepal staff for their support following the earthquake in April 2015. Then I would like to thank Inga Bucholz, Bianca van der Kroon, Pieter van der Beukering and again Bart-Jan van Beuzekom for their support and guidance in the process of redefining the research topic. Finally a special thanks to the EnDev staff of all the researched countries for providing the data on which this research is based.

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Abstract

With the recognition that access to modern energy is crucial for poverty alleviation, electrification efforts now focus on SMEs. Through productive use of energy (PUE) in SMEs, electrification can be the source of sustained economic growth. It is however found that PUE does not always lead to economic development. Not knowing why this is the case makes it difficult to design and predict outcomes of electrification interventions. To better understand the relation between PUE and economic development this research tries to find how PUEs develop over time. Within the context of this study it was found that the number of PUEs at a site will increase over time after it has been electrified, even more so if PUE is actively promoted. The type of PUEs that will develop is not influenced by the industry types in a countries economy. Neither does its development follow any trends or shifts between industry types that occur in the economy. The development of different types of PUE over time also does not follow the traditional model of economic development. Instead the types of PUE that will develop are determined by local circumstances. This makes it possible to support a specific industry by focusing electrification efforts on areas where the local context is most likely to develop the desired type of PUE.

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List of abbreviations

CREE Community Rural Electrification Entity
ECG Electricity Company of Ghana
EnDev Energising Development
ESDM Ministry of Energy and Mineral Resources
GDP Gross Domestic Product
KUKM Cooperatives and Small-, and Medium enterprises
LIZ Light Industrial Zone
MHP Micro Hydropower
MSP Micro grid Service Package
NEA National Energy Authority
NEDco Northern Electricity Distribution company
PUE Productive Use of Energy
SME Small-, and Medium Enterprise
UNDP United Nations Development Program
VMT Village Management Team

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1 Introduction

1.1 Problem statement

"Ensure access to affordable, reliable, sustainable and modern energy for all" (UN, 2015). This is one of the UN's 17 sustainable development goals for 2030. It was included after in the millennium development goals it had been recognized that energy is crucial for alleviating poverty (UNDP, 2005). In poverty stricken areas around the world interventions are taking place that try to bring modern energy carriers to households, social institutions and Small-, and Medium Enterprises (SMEs). It is believed that in SMEs, access to modern energy can serve as a basis for sustainable economic growth (Energy U.N., 2005). In SMEs energy can be used to generate income, this is referred to as Productive Use of Energy (PUE). It allows SMEs to increase production and produce more efficient. The additional income that comes from this helps people break out of the poverty trap (Barnett, 2000).

One of the modern energy carriers that are used is electricity. Electrification interventions for SMEs come in different forms, use different technologies and take place in different settings. This has led to the electrification of a diverse group of enterprises using electricity in a variety of ways. As expected these PUEs contributed to economic development in some cases (Khan et al. 2002; Dinkelman, 2011). However there are also many cases in which no economic development followed directly from PUE (World Bank OED, 1995; Matly, 2003; Kooijman van Dijk, 2008; Kooijman van Dijk and Clancy, 2010). More research is needed to understand how PUE actually contributes to economic development (Kooijman van Dijk, 2008). Attempts have been made to link traditional models of economic development to electrification and PUE. It is however questioned whether these models hold in currently developing economies (van Ruijven et al., 2008). It is therefore currently not known how PUEs will develop over time.

Not knowing how PUEs will develop over time makes it difficult to plan electrification interventions. It also makes it difficult to transfer knowledge from one electrification intervention to the next. In different countries, the development of PUEs is currently in different stages. There is therefore a potential for the more recent interventions to learn lessons from interventions that have been going on for longer. It seems that ongoing and future electrification interventions with PUE components could clearly benefit from knowing how PUEs will develop over time.

1.2 Research objective

This research tries to find out how PUEs develop over time in electrification interventions. This is done by analyzing monitoring data from several countries in which the global program Energising Development (EnDev) has carried out electrification interventions with PUE components. Looking at how the PUEs developed in these interventions will provide the basis to draw several conclusions on PUE development in general. These can then serve as a basis for designing and predicting outcomes of future electrification interventions.

1.3 Research Question

Based on monitoring data from past electrification interventions with a PUE component, the development of these PUEs is researched. That main question states: *"In what way do Productive Uses of Energy develop over time in electrification interventions?"* To help answering this question the following sub questions were derived:

- What PUEs exist?
- What technologies are used for PUEs?
- How can the PUEs be categorized?
- Is there a pattern in PUE development?
- What external factors influence PUE development?
- What internal factors influence PUE development?

This research starts with an overview of relevant literature, followed by a description of the used methodology, after which the findings are presented and analyzed. From this several conclusions are drawn and their implications are discussed. Finally the limitations of this research are reviewed.

2 Literature review

2.1 Electrification and economic development

At the 2002 world summit in Johannesburg, access to energy was said to be critical for poverty alleviation. UNDP (2005) called access to modern energy a key enabler for the alleviation of poverty. In light of this, developing energy services is essential for achieving the Millennium Development Goals (Modi et al., 2005). In the Sustainable Development Goals that follow up on the Millennium Development Goals in 2015, one of the 17 main goals is even dedicated to the access to electricity. The goal is to "Ensure access to affordable, reliable, sustainable and modern energy for all" (UN, 2015). Van Ruijven et al. (2012) define benefits of access to modern fuels like electricity at three levels. First, at the community level electricity can offer improvements in terms of education, health and water supply. Second, at the household level the access to electricity leads to improved indoor air quality, education and hygiene. The third level is the enterprise level consisting of small-, and medium private enterprises (SMEs). SMEs can use electricity for mechanization of production processes, enhanced computerization and communication. Focusing electrification efforts on SMEs is believed to not only benefit the enterprise itself, but also the surrounding community. In this way electrification becomes the source of sustained economic growth through generating jobs, industrial activity, transportation, commerce and agricultural output (Energy U.N., 2005).

The existence of these benefits from electrification of SMEs is supported by the findings of Dinkelman (2011) who found that electrification had a positive effect on employment in rural communities in KwaZulu-Natal, South Africa. Khan et al. (2002) in their study in Bangladesh found that in electrified areas people have a significant higher income and employment rates are higher as well. They also found that in agricultural businesses the crop yield was higher where electricity was used for irrigation.

The above mentioned benefits can in more general terms be explained by the use of electricity for income generation. Poor enterprises are believed to make decisions based on current cost even if alternatives are cheaper in the long run. This is caused by the upfront investment that is needed to switch to cheaper fuel sources, which poor enterprises are usually unable to afford (Reddy and Reddy, 1994). This forces them to keep working with less efficient and more expensive production methods which in turn inhibits income growth, making them again unable to invest in alternative fuel sources. This vicious cycle is known as the poverty trap (Barnett, 2000). By providing enterprises with a modern energy carrier like electricity, this cycle can be broken.

2.2 Benefits of electricity in SMEs

To better understand how electrification helps SMEs to get out of the poverty trap, several studies have looked at how electricity is used in these businesses. Kaygusuz (2011) found that in agriculture, which is a common industry in poor areas, electricity can be used to replace labor by animals or humans. It can be used for irrigation, mechanization and transport. This indirectly frees up capital for the farmer who for instance could use it to invest in modern fertilizers which increase crop yield. In non-agricultural rural industries he found the main uses of electricity to be lighting, process heat and motion power.

Kooijman van Dijk and Clancy (2010) identify three types of services electrification can bring to rural SMEs. First, by providing lighting, the enterprise can enjoy longer and more flexible production hours.

This will in turn lead to increased productivity. Secondly, electricity can be used for different processes, replacing manual labor. This also has positive effects on productivity and frees up laborers time for other activities. The third service is considered to be water pumping. Electric pumps, replacing diesel or manual powered ones, reduce fuel cost and the environmental impact. That electrification contributes to reducing environmental impact is also supported by the study of Kooijman-van Dijk, 2012. She reasons that because SMEs are accountable for a big part of total energy consumption in poor areas, and electricity is less polluting than the fuels that are currently being used, the use of electricity will help reduce emissions. In addition to the earlier mentioned benefits, Kooijman van Dijk and Clancy (2010) also found that electrification gives enterprises the time and opportunity to diversify. This could then create additional income for the enterprise.

However, it seems that the above mentioned benefits for SMEs somehow do not always result in economic growth for the area. In a study by the World Bank OED (1995) in several Asian countries, no evidence was found for economic growth that followed from electrification. Hjort-af-Ornas (2008) found that 30 years after electrification, the number of SMEs in the town of Isiolio in central Kenya only increased from 96 to 98. In this period the average revenue of the SMEs only increased due to inflation. Kooijman van Dijk (2008) concludes after a literature review that the causal relation between energy and income generation requires further research. Kooijman van Dijk and Clancy (2010) conclude from a study in Bolivia, Tanzania and Vietnam that electricity brings more non-monetary benefits than monetary benefits to SMEs. The non-monetary benefits come from the new products and services an electrified SME can offer.

Further investigating the relation between electrification and economic development, Van Ruijven et al., 2008 describe 2 reasons why increased income and electrification might not positively reinforce each other to create sustained economic growth. First of all electrification interventions do not always have a proper support system in place. Without proper service and maintenance the electrification installation could become useless (Mulugetta et al. 2000). Second there are other challenges like market development and access, access to credit facilities and willingness to pay of customers for higher quality products. These might still inhibit economic growth after an SME is connected to electricity (Kooijman van Dijk, 2005).

Kooijman van Dijk and Clancy (2009) found that electrification almost always provides welfare benefits, however the monetary benefits SMEs can enjoy are highly dependent on their market access. Local markets were found to be quite balanced, meaning that increased production for one local enterprise meant diminishing returns for another. Also in remote rural areas there is usually little demand for diversified products. This means that only in places where there is access to non-local markets, enterprises could benefit from a diversified product portfolio or increased production. That this diversification takes place was observed by Hjord-af-Omas (2008).He observed significant diversification among SMEs, mostly into industries that require electricity like garages, carpentry and hotels. Also after a period of 30 years, all SMEs in his study were now using electricity. A similar movement was observed by Khan et al. (2002) in Bangladesh where a shift towards non-agricultural industries was observed.

It seems that this diversification plays a key role in understanding how electrification of SMEs can lead to economic development. It would therefore be beneficial if this process of diversification is better understood.

2.3 Analytical framework

To understand the diversification in economic activities and economic growth it is necessary to first understand how economies are structured and how they develop in general. The size of an economy is expressed in Gross Domestic Product (GDP). This is the sum of the total value of all products and services produced in a Country. All products and services that are produced can be divided into three industry sectors (Clark, 1940). The primary sector of industry is the extraction of raw materials from the earth. Although this could for instance also include mining operations, in electrification it generally refers to agricultural processes (van Ruijven et al., 2008). The secondary sector is the manufacturing industry. This sector contains all business activities where raw materials are turned into goods. The tertiary sector entails the exchange of services.

As economies develop they do not only grow in size but also change in composition. Clark (1940) related economic development to a shift from the primary sector towards the secondary and tertiary sector (Wolfe, 1955). Jung et al. (2002) linked the development of the manufacturing industry to GDP growth. They did this by looking at historical data from countries that are nowadays believed to be developed countries. They found that economic and therefore GDP growth follows from a rapid growth in the manufacturing industry. As an economy becomes more developed, the growth in manufacturing industry will stabilize.

Van Ruijven et al. (2008) in their study on models for relating energy to economic development, created a model based on that of Jung et al. (2002) which shows how economies are expected to develop over time. This model is displayed in Figure 2-1. It can be seen that at first when a country is in the 'under developed' phase, the main share of its employment and GDP comes from agriculture. In the next phase of development the manufacturing industry thrives. At this point a country enters the 'developing' phase where the economy holds an equal share of agricultural and manufacturing industry. At a certain point the service industry begins to develop, this diminishes the share of agriculture in the economy even further. At this point the growth in manufacturing stabilizes (Jung, 2002) and the service industry continues to grow. Due to this the relative share of the manufacturing industry diminishes. At this point the country enters the 'newly developed' phase. The service industry will continue to grow until there is a predominantly service orientated industry which is seen in the 'developed' world.

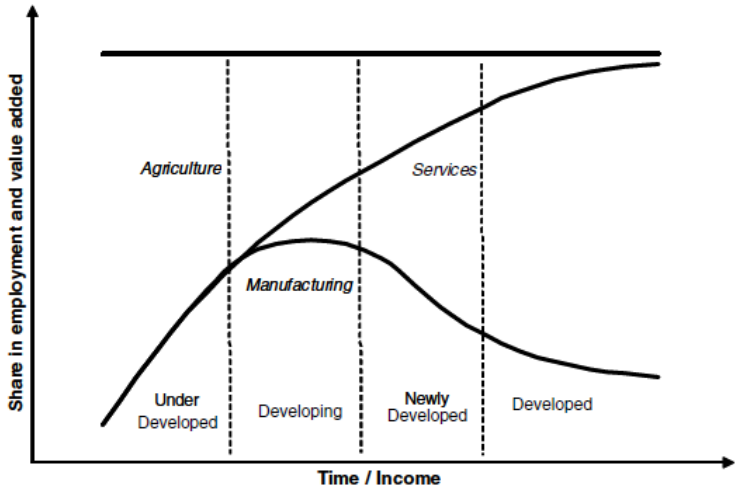

Figure 2-1, Economic development Source: Ruijven et al. (2008)

Jung et al. (2002) found evidence for this pattern in historical data. Also Hjord-af-Omas (2008) and Khan et al. (2002) witnessed a similar industry shift in electrification projects. However, Jung et al. (2002) question whether the model holds in the context of currently developing countries. They believe that the difference in natural resources, human resources, heterogeneous backgrounds and various economic systems will influence the way in which economies will develop. Van Ruijven et al. (2008) themselves also question whether their model is still applicable. First of all they believe that the outsourcing of production from developed countries to less developed countries could be a factor that influences industry composition in developing countries. Second they describe the process of 'leapfrogging' as a possible cause for different patterns in currently developing countries. Leapfrogging entails skipping gradual process through less advanced and more polluting fuel and directly start using more advanced and less polluting energy forms (Kumar, 2015). Zhang (2014), based on data from 45 World Bank projects in 39 countries, found evidence for the existence of leapfrogging in the case of solar PV electrification interventions. In these cases it was found that it is possible to leapfrog the step to grid electrification and immediately move to sustainable energy from solar PV. He also suggests that with access to credit facilities it is possible to leapfrog energy subsidies. What the model for economic development looks like when these processes are taken into account is not yet known.

2.4 Conclusion from theory

Given that electrification of SMEs provides additional benefits compared to the electrification of households makes it interesting to focus electrification efforts on SMEs. But although SMEs generally enjoy several benefits from access to electricity, electrification does not necessarily lead to economic growth. To understand under what circumstances electrification does lead to economic growth, the general process of economic development has to be understood.

The traditional model of economic development in which a shift between three economic sectors occurs at first also seems to hold for electrification interventions. However, the question is raised whether this model still holds in the countries where the electrification interventions are currently taking place. There are indications of several processes that disrupt the way economies around electrification interventions currently develop. For the design and prediction of outcomes from electrification interventions, it can be beneficial to understand whether the traditional model of economic development still holds or in what other way economies around electrification interventions develop. With this information it could be possible to better predict outcomes of electrification interventions. This makes it possible to focus and appropriate electrification efforts.

3 Method

3.1 Research setting

The Energizing Development (EnDev) program aims to bring sustainable energy to 24 developing countries in Asia, Africa and Latin America. EnDev is a multi-donor program funded by the Netherlands, Germany, Norway, Australia, the United Kingdom and Switzerland and coordinated by GIZ in Germany. The idea is that long term access to sustainable energy will help relieve poverty. EnDev brings energy to households, social institutions and small enterprises using a variety of technologies. An overview of all the counties and technologies is given in Figure 3-1.

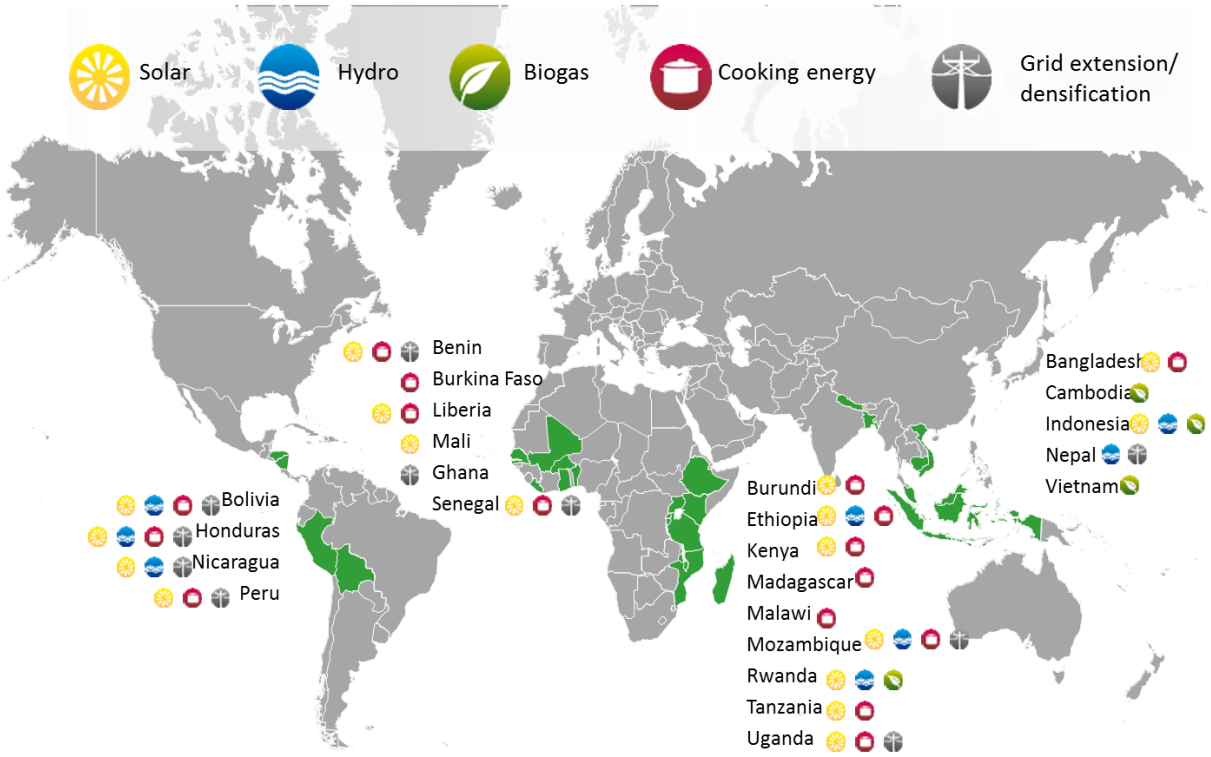

Figure 3-1, EnDev activities worldwide **Source: EnDev (2015a)**

In 2010 EnDev entered phase 2. This second phase will run approximately till 2015. The program aims to provide one person with access to modern energy for every 20 euro spent and to reduce health risks from inefficient cooking methods by 50% for at least 3 million people of whom at least 2/3th are woman and children. In addition it focusses on developing the energy markets in the 24 EnDev countries and promoting climate friendly technologies. No specific goals for PUE were defined in Phase 1 and 2.

By the end of 2014 EnDev phase 1 and 2 combined had globally brought electricity to 3,45 million people and efficient cooking technology to another 10,45 million. In 17 of the 24 program countries a PUE component was introduced serving a total of 32.424 enterprises. With an average cost efficiency of €14,04 per person, EnDev phase 2 even surpassed its goal of €20 euro a person.

With EnDev phase 3 starting in 2015, goals have been adjusted to include targets for electrification of enterprises and social institutions, targets for creating job opportunities and an even stronger focus on the use of sustainable technologies.

3.2 Research design

This research will be based on monitoring data from three different EnDev countries in which PUE interventions are carried out. The chosen countries are Ghana, Indonesia and Nepal. The countries were chosen because they have significant experience in PUE interventions and sufficient data on these interventions is available. Besides looking at the absolute number of enterprises connected in PUE interventions, the context in which the interventions take place will be described.

By looking at different countries it is possible to study PUEs in different contexts. Studying multiple countries will also make the outcomes more generalizable then when a single case study would be used (Yin, 2003). This research is of an exploratory nature as it is not yet known how PUEs develop over time. In line with the exploratory nature a qualitative approach is taken (Saunders et al., 2011). So instead of statistically analyzing the absolute numbers, they will be interpreted qualitatively.

This research will be limited to the productive use of electric energy. PUE also comes in the form of thermal energy. This mainly consists of the use of improved cooking facilities for commercial purposes. These are for instance food vendors and restaurants. However because of this limited applicability of thermal energy it will not be included in this study.

3.3 Data collection and analysis

In each country the number of connected households, social institutions and enterprises is recorded bi-annually. This monitoring data and other relevant reports were collected by sending the requests to the respective country representatives. This was done in collaboration with the EnDev main office in Eschborn Germany.

The findings and analysis start with a description of the country's economic and energy situation. This will give a general indication of the context in which the electrification interventions take place. Next a description of all EnDev program activities within each country, including the goals and achievements, is given. After this the PUE activities in each country are described and compared. First the development of PUEs over time is described. Next the PUEs are classified according to their respective industry type. This makes it possible to compare the share of each industry type in the PUEs with that in the country's economy. Also the development of industry types in PUEs over time is plotted. This makes it possible to see whether the theoretical framework holds in the case of the three selected countries. Looking at the relative share each industry type holds in the total amount of PUEs makes it possible to compare countries even when there are differences in absolute number of PUEs.

Besides looking at each country individually the countries are compared. Any differences and similarities between countries are identified. Explanations for these similarities and differences are sought which will lead to several conclusions. Finally the implications of these conclusions for current and future electrification interventions are discussed.

4 Findings and analysis

4.1 Country profile and energy situation

4.1.1 Economy and industry

The country's economic situations are analyzed by looking at their type and growth. As can be seen in Table 4-1 Ghana is experiencing the largest economic growth of the three countries, also the rate at which the economy grows has increased over the past 10 years. Indonesia also experiences economic growth but the growth has more or less stabilized. Nepal shows the smallest economic growth of the three countries but it is increasing.

Table 4-1, Population, electrification and economic growth **Source: Worldbank databank (n.d.)**

	Population		Electrification rate		Average annual GDP growth	
Country	Total	Rural	Total	Rural	2003-2007	2008-2012
Ghana	25.366.462	47.9%	64.1%	41.0%	5.92%	8.60%
Indonesia	246.864.191	48.5%	96%	92.9%	5.56%	5.80%
Nepal	27.474.377	82.5%	76.3%	71.6%	3.78%	4.74%

The share of the different industries in the country's economy is displayed in Figure 4-1, Figure 4-2 and Figure 4-3 for Ghana, Indonesia and Nepal respectively. The data is presented for the same period EnDev phase 2 took place. Ghana's economy shows a diminishing share of agriculture and increasing share of manufacturing and service industry. Combined with the increasing economic growth, according to Jung et al., (2002) and van Ruijven et al. (2008), this makes Ghana a 'developing' economy. It should however be noted that big differences exist between north and south Ghana. In Ghana most settlements and industrial activities are located in the southern part of the country while the northern part is predominantly used for agricultural activity (Energypedia, 2014a).

In Indonesia agriculture holds a relatively small (14%) but stable share of the economy. Meanwhile the service industry is growing at the expense of the manufacturing industry. Together with the stable growing economy, according to Jung et al., (2002) and van Ruijven et al. (2008), this makes Indonesia a 'newly developed' economy. Also here it should be mentioned that large differences are observed between the different islands in Indonesia (Ares, 2013).

In Nepal agriculture still holds a large (35%) share of the economy compared to the other countries. The manufacturing industry is rather small (14%) while the service industry takes up the largest share. Although the limited growth and small share of manufacturing industry would make it an 'under developed' economy according to Jung et al. (2002). However this does not explain the large share of the service industry. It could be that because the economy of Nepal started developing later than the other two countries it is experiencing what van Ruijven et al. (2008) describe as leapfrogging. This means that the access to recently developed technologies has caused the service industry to develop without the expected preceding growth of the manufacturing industry.

4.1.2 Grid and electrification

Table 4-1 shows the electrification rates of the three countries for both the rural and total population. Although the electrification rate in Indonesia is relatively high compared to the other countries, it is considered quite low for a middle income country. Also because it has a much larger population than the other countries the total number of people without electricity is rather large.

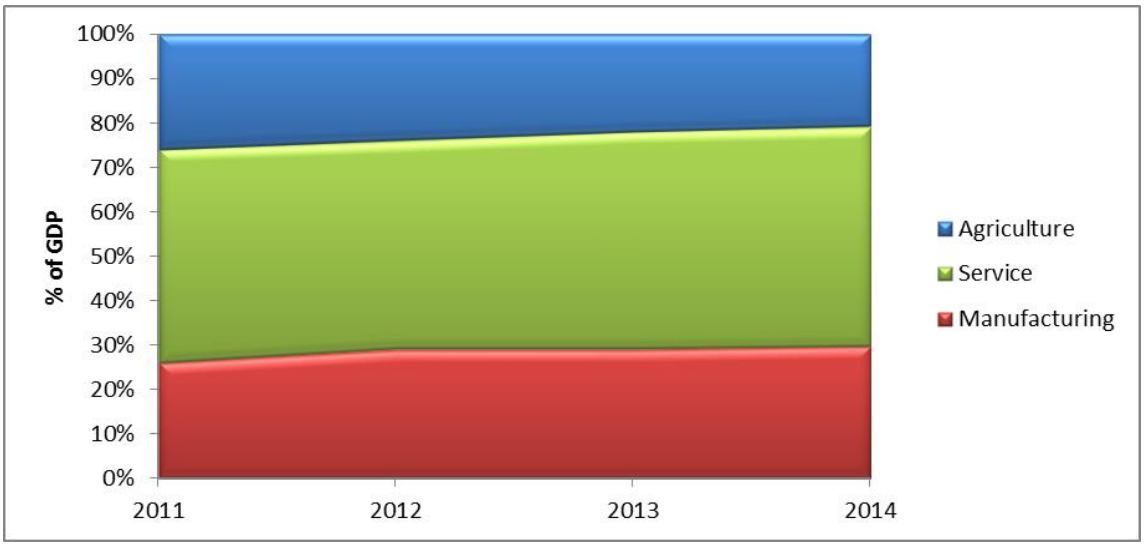

Figure 4-1, Industry development in economy Ghana Source: Worldbank databank (n.d.)

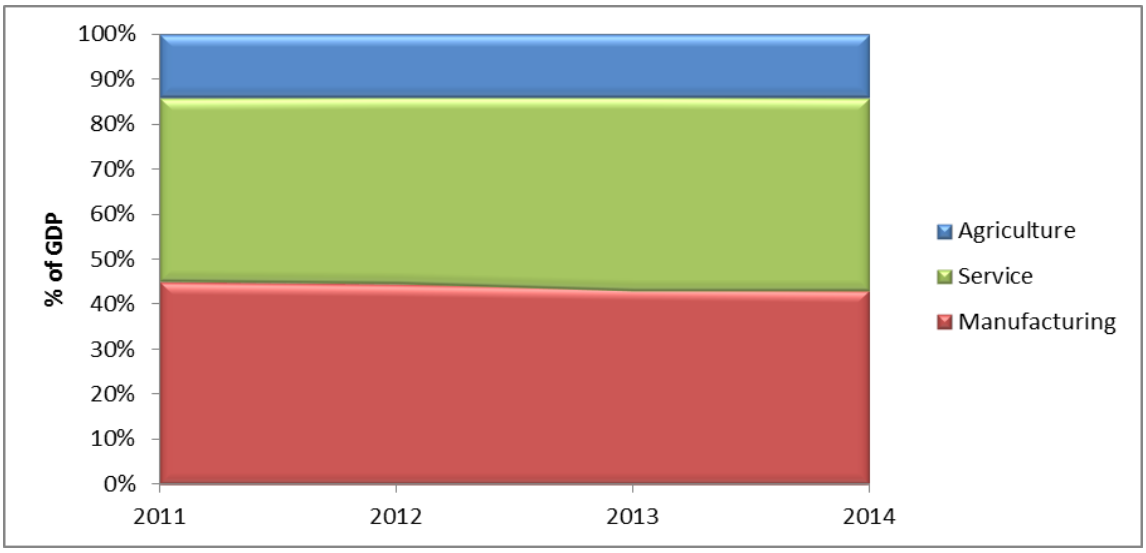

Figure 4-2, Industry development in economy Indonesia Source: Worldbank databank (n.d.)

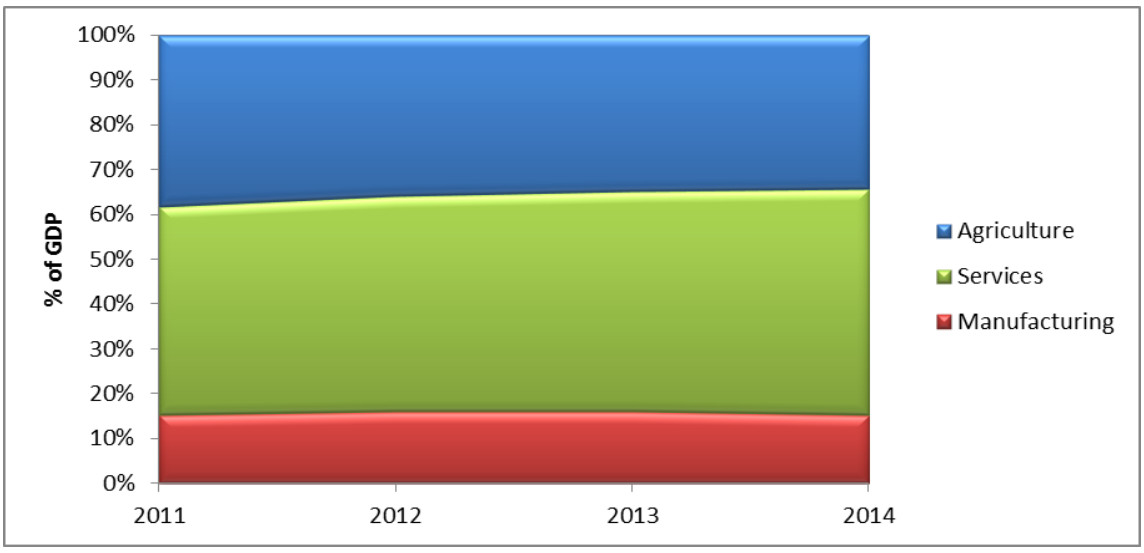

Figure 4-3, Industry development in economy Nepal Source: Worldbank databank (n.d.)

In all countries the energy situation shows big differences within the country itself. The electricity grid in Ghana is managed by two separate companies. The northern half is managed by the Northern Electricity Distribution Company (NEDco). Electrification rates here are as low as 34%. In the southern half of the country distribution is managed by the Electricity Company of Ghana (ECG). The southern part accounts for 90% of total power consumption in Ghana. Although grid coverage is quite extensive, the connection rates at the edges of towns are relatively low (Energypedia, 2014a).

In Indonesia similar differences exist between different islands. 60% of all power is produced by the national utility PLN and distributed across the grid displayed in Figure 4-6. 80% of all power is consumed on Java and Bali where a little over 50% of the population lives. In the more remote mountainous areas there is a large potential for hydropower but this largely remains untapped. Out of the non-electrified people, around 50% live in electrified regions but don't have any connection, the remaining 50% lives in more remote rural areas (Ares, 2013).

In Nepal the national grid only covers the central Kathmandu valley and the southern half of the country. In the Northern half of the country which consists of the Himalayan mountain range people are dependent on off-grid solutions like diesel generators or renewable energy sources. Electrification rates here can run as low as 4.7%. Even in areas with a grid connection, beneficiaries are subjected to severe load shedding due to capacity shortages (Energypedia, 2014b).

4.2 EnDev program activities and achievements

An overview of EnDev activities in Ghana is given in Figure 4-4. In Ghana, GIZ together with SNV Netherlands and Ghana Ministry of Power, focus on 4 EnDev program components. The first is to support 250 farmers in the process to gaining access to grid electricity for irrigation. This project will take place in the eastern part of Ghana, along the border with Togo. By the end of 2014 a stakeholder workshop was held and application for potential beneficiaries was opened. The second component is providing 25 small scale farms with solar powered irrigation. By the end of 2014 potential suppliers of solar irrigation equipment in Ghana had been identified. The third component is supporting 300 gari (storable fermented flour) processors. By the end of 2014 the existing gari processors had been mapped and 2 demonstration installations were under construction. The fourth and final component is the continuous monitoring and support for grid extension and densification programs in Light Industrial Zones (LIZ). These are zones on the outskirts of settlements where a lot of SMEs are based. Although these areas are covered by the national grid, most SMEs are generally not connected.

In Indonesia EnDev has a separate biogas and electrification program. By 2014 the biogas program had managed to construct 2.700 digesters reaching 11.408 people. The electrification efforts consist of the construction of mini grids powered by either hydro or solar power. An overview of the locations is given in Figure 4-5. By the end of 2014, 239 micro hydro power (MHP) and 222 solar power mini grids had been constructed. All installations are managed and operated by the community.

Instead of focusing on direct implementation of projects, EnDev Indonesia tries to support the development of the relevant sectors. As part of a mini grid service package (MSP) they do technical commissioning and inspection, conduct baseline socio-economic surveys, give training to Village Management Teams (VMT) and operate a SMS hotline. MSP is also available for non-EnDev projects. The most important partner of EnDev in Indonesia is the Ministry of Energy and Mineral Resources

(ESDM) who in some projects covers the cost of hardware and installation expenses. To further promote PUE, EnDev Indonesia started working with the Cooperatives and Small and Medium Enterprises (KUKM) in November 2013. In total PUE training was given at 11 MHP sites.

An overview of all EnDev activities in Nepal is given in Figure 4-6. The program has three main components which are all focused on electrification of rural communities. The first component is providing support to the National Electricity Authority (NEA) in their Community Rural Electrification Program (CREP) which is aimed at grid extension projects. EnDev provides funding and other means of support to Community Rural Electrification Entities (CREEs). The second component aims to establish MHP plants using the micro hydro debt fund (MHDF). The third component aims at helping CREEs to promote PUE. This is done in collaboration with Helvetas Swiss and the National Association of Community Electricity Users Nepal (NACEUN). It is believed to improve the project's long term economic sustainability. In this two year program the first year is used for capacity building and the PUEs are expected to develop in the second year. After a successful pilot at 4 CREEs, the PUE promotion program is now extended to another 4 CREEs.

The total number of households, social institutions and SMEs that were connected in each country by December 2014 is given in Table 4-2.

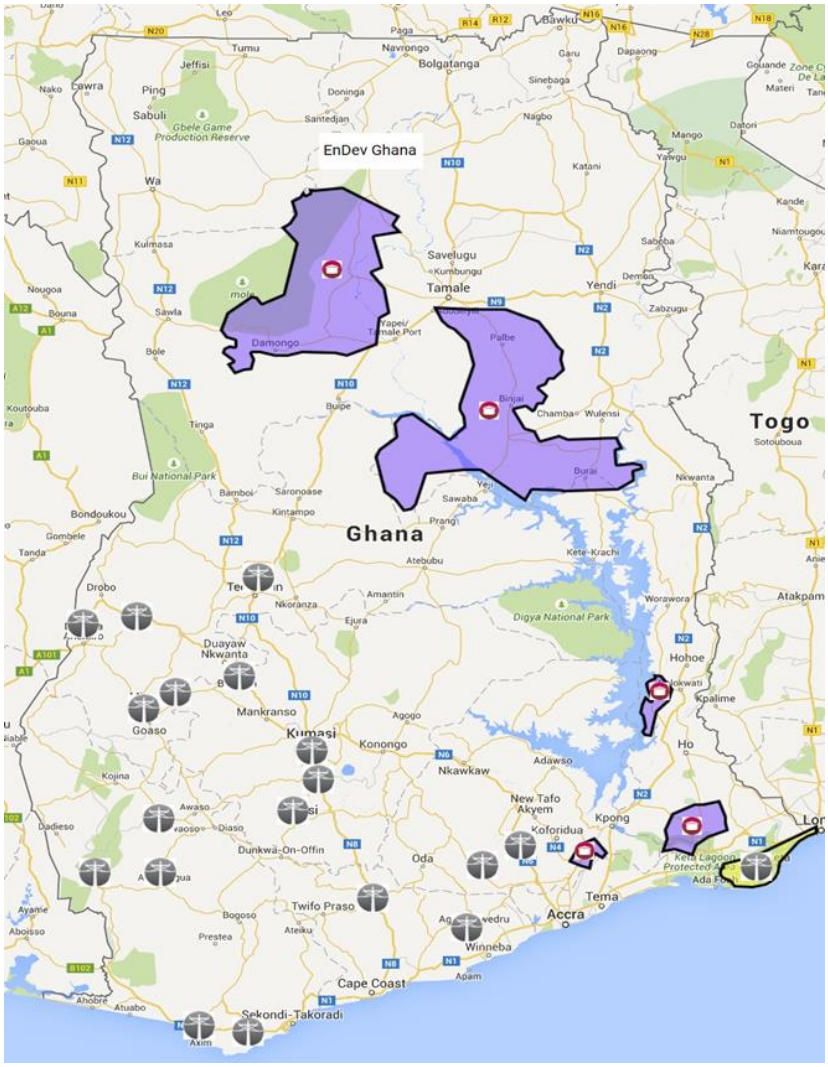

Figure 4-4, Overview of EnDev activities in Ghana **Source: Endev (2015b)**

Figure 4-5, Overview of EnDev activities in Indonesia **Source: EnDev (2015c)**

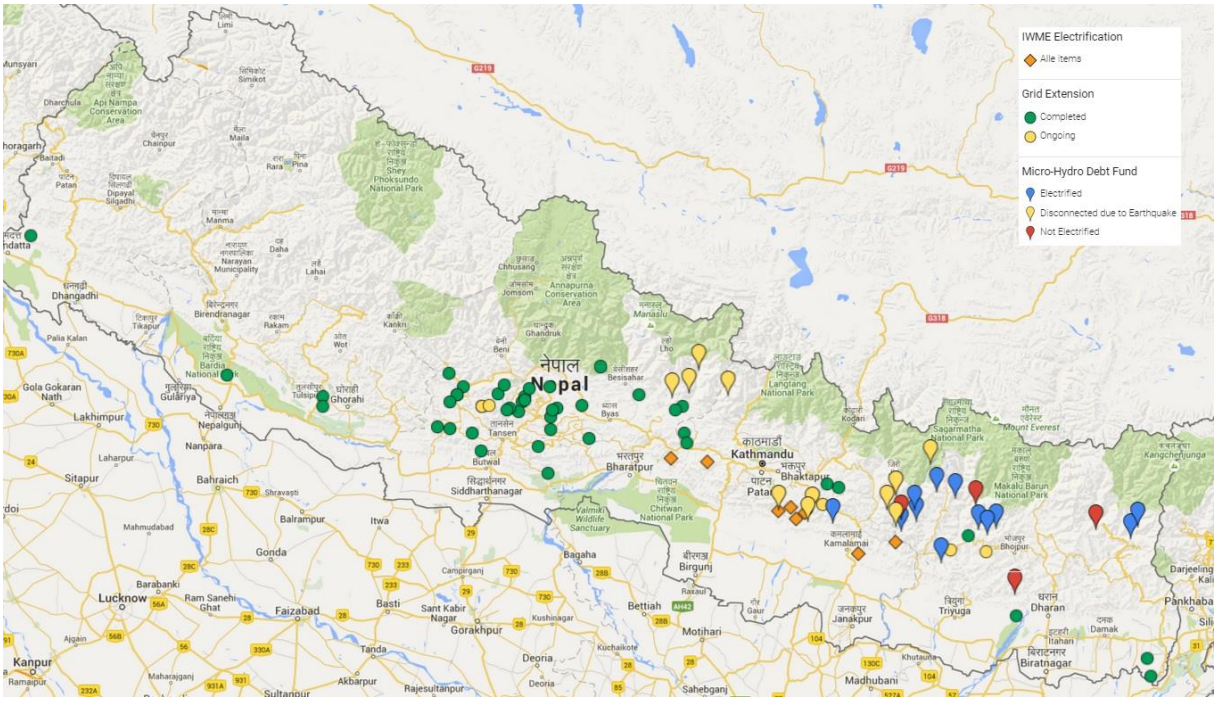

Figure 4-6, Overview of EnDev activities in Nepal **Source: EnDev (2015d)**

Table 4-2, EnDev achievements December 2014 **Source: EnDev (2015a)**

Country	Households	Social institutions	SMEs
Ghana	1.526	Street lighting in 8 zones	350
Indonesia	142.149	1.083	2.125
Nepal	237.000	842	1.288

4.3 Amount of PUEs

4.3.1 Connected SMEs

For monitoring purposes the number of connected SMEs at each site is recorded. Also the type of business is described. In some of the countries the monitoring data shows more extensive descriptions of the businesses than in others.

Of the four project components EnDev has in Ghana, only component one, two and four concern electricity for productive use. Because by December 2014 component one and two had yet to be implemented, the reported 350 connected SMEs are all part of component 4. They are located in a total of 10 LIZs averaging 35 SMEs per LIZ. All businesses can be categorized into 10 types. The different types of businesses and their development overtime are displayed in Figure 4-7. The total number of SMEs shows a slight decrease around July 2013, this was predominantly caused by the disconnection of a group of auto body workshops at one site.

In Indonesia productive use interventions started with MHP powered mini grids. Starting from 2013, also mini grids powered by solar panels are used for productive use interventions. By December 2014 a total of 1.637 SMEs were powered by MHP installations. Divided across the 239 sites this gives an average of just under 7 SMEs per site. Another 1.026 SMEs are powered by solar mini grids. Spread across 222 sites this gives an average of between for and 5 SMEs per site. The different uses, number of enterprises and their development over time are displayed in Figure 4-8 and Figure 4-9 for MHP and solar power respectively.

Productive use activities in Nepal are undertaken in the context of the grid extension component. Once remote rural communities are connected to the grid, the NEA sells bulk power to so-called CREEs. Those organizations founded and operated by the communities are responsible for the operation and management of the distribution network, collection of revenues from villagers and payment for bulk power purchased from NEA. By December 2014 1.111 enterprises were connected across 49 CREEs averaging between 22 and 23 enterprises per CREE. All enterprises are divided into 10 categories. The amount of enterprises in the different categories and their development over time are displayed in Figure 4-10.

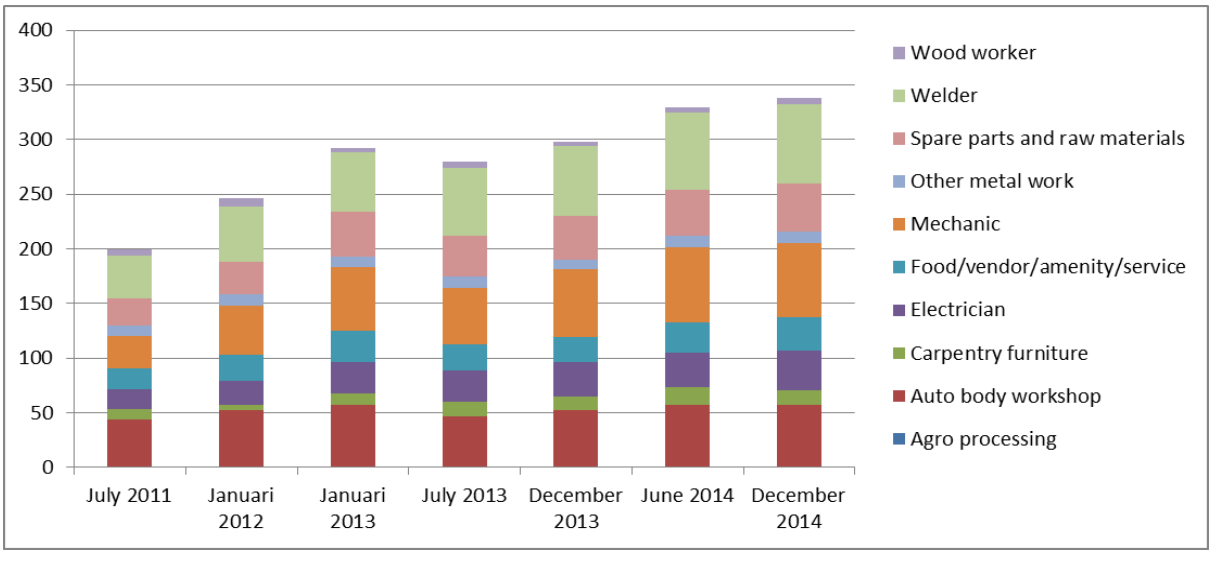

Figure 4-7, Total number of EnDev supported PUEs in Ghana

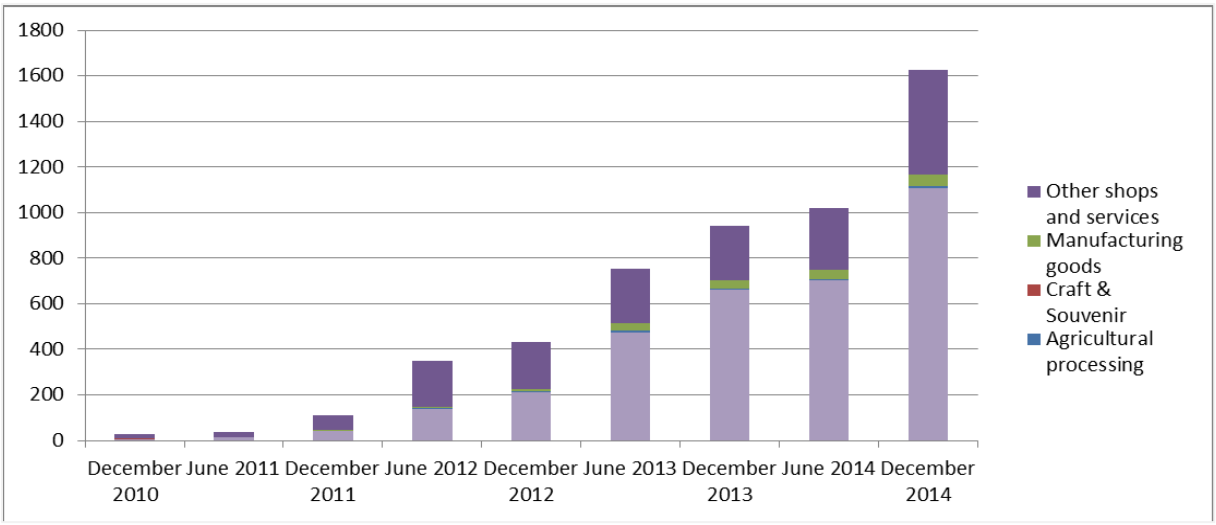

Figure 4-8, Total number of EnDev supported PUEs in Indonesia (MHP)

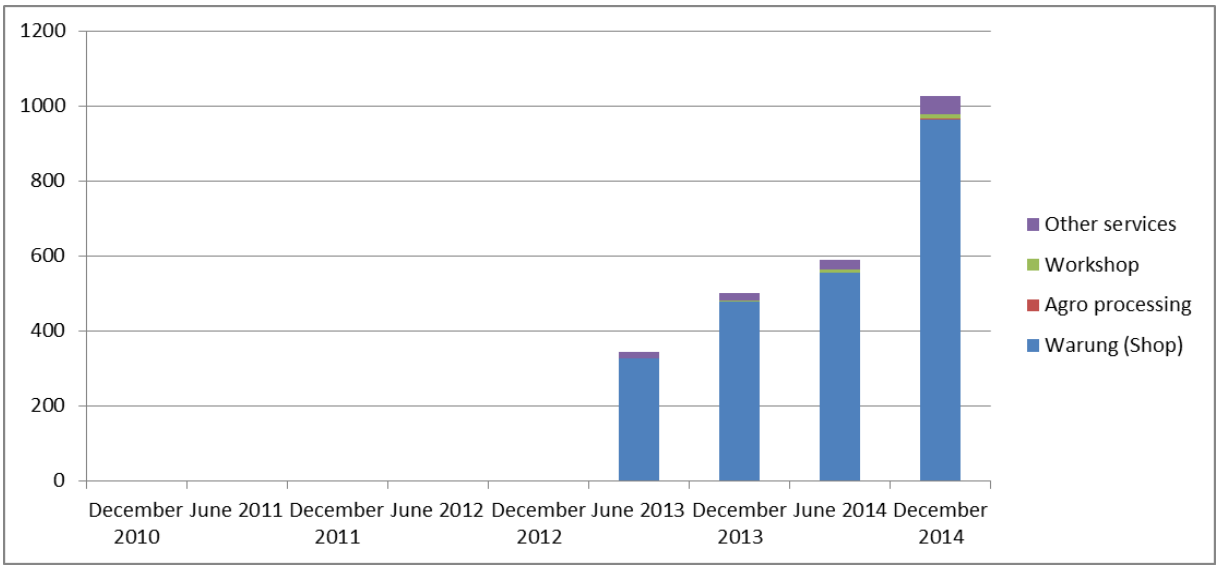

Figure 4-9, Total number of EnDev supported PUEs in Indonesia (Solar)

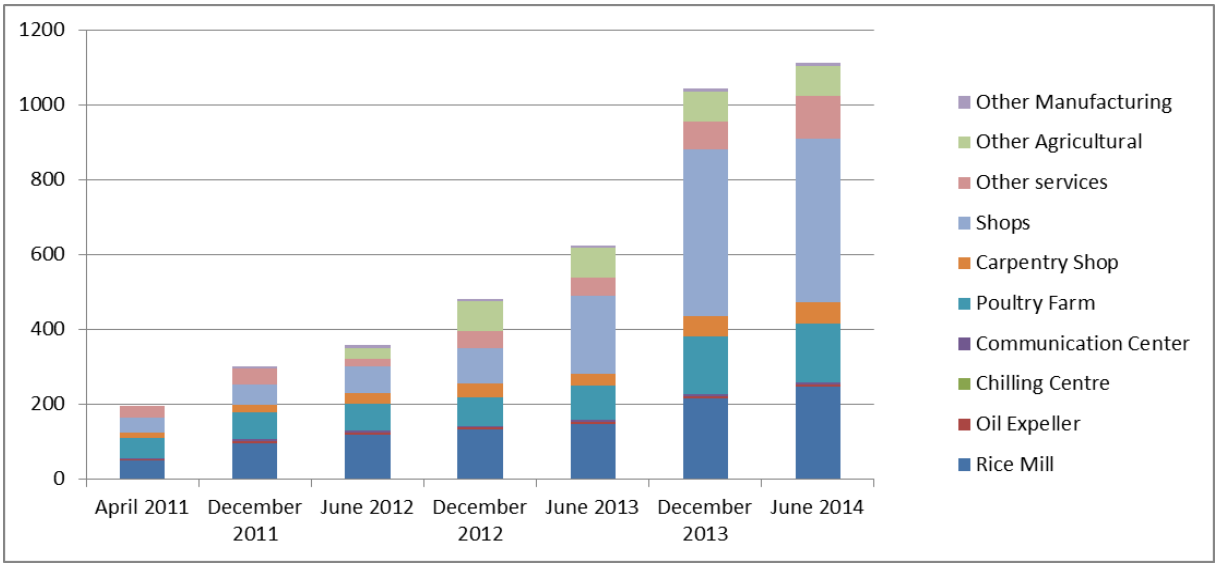

Figure 4-10, Total number of EnDev supported PUEs in Nepal

4.3.2 PUE development over time

All countries display an increase of PUE over time. This is however partialy explained by an increasing number of sites at which the interventions take place. In Ghana only 6 out of the 10 CREEs were connected in 2011, the other four were connected in 2013. In Indonesia and Nepal the number of sites gradually incraesed between 2010 and 2014. In order to see whether the number of PUEs at individial sites also increases over time, the connection dates have to be taken into account. This makes it possible to see what happens over time to the number of connected PUEs after a site is electrified.

Figure 4-11 shows the avarage number of PUEs at a certain number of months after connection in the LIZs in Ghana. It is clear that number of PUEs increases over time after a site has been electrified. There is however no clear patern visible. Figure 4-12 shows the development in Nepal. Here there is also a clearly visible increase in number PUEs per site. The growth seems to follow a more or less linear trend with 7 new PUEs being added per year. Because the monitoring data is only available from April 2011 until June 2014 the graph is based on 25 of the total 49 CREEs. Other CREEs had either failed to develop any productive uses, were too old or new to fall within the range of the others or their connection date was unknown. An overview of which CREEs were included for each datapoint is given in appendix A.

The development in Indonesia could not be analyzed because the data shows no new PUEs after initial connection. This means that the number of PUEs per site remains constant.

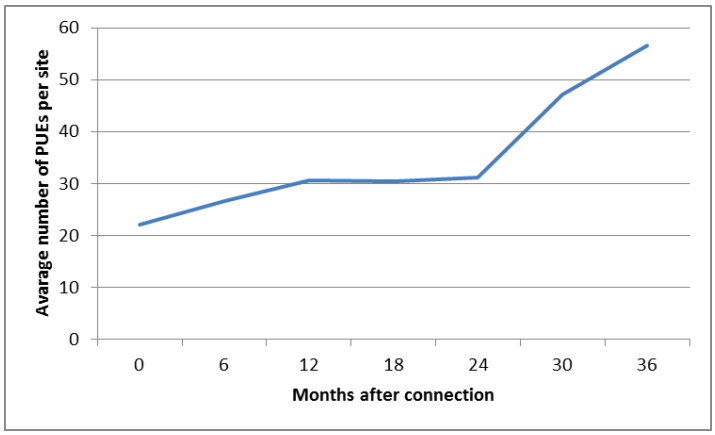

Figure 4-11, Average number of PUEs per site in Ghana

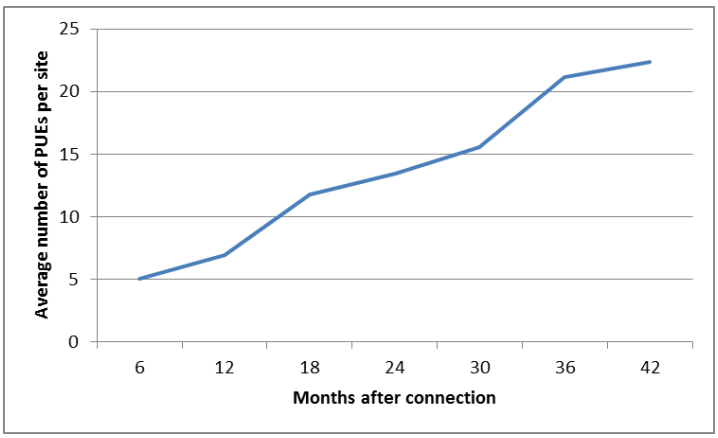

Figure 4-12, Average number of PUEs per site in Nepal

The PUE promotion program that was piloted at 4 CREEs was ment to start in October 2012 and run untill October 2014. However due to some delays it was actually started in April 2013. The number of connected enterprises before and after the promotion program are displayed in Table 4-3. At CREE 23 the promotion started almost 5 years after it was electrified. At this time 15 SMEs were connected. During the promotion program another 45 SMEs were connected bringing the total to 60. At CREE 25 the promotion program started almost 7 years after it was electrified. In this time 20 SMEs were connected. During the 2 year program another 18 SMEs were connected. At CREE 39, 21 SMEs were connected in the 10 months before the promotion program. During the program another 21 were connected. At CREE 44 no SMEs were connected in the 6 years before the promotion program. With the program there were 57 SMEs connected. At all four CREEs the annual increase in number of PUEs exceeds the avarage of 7 PUEs found at the other CREEs. In three of the four CREEs there were more SMEs connected annualy during the program than in the years before. Only in CREE 39 there were more SMEs connected in a shorter time period before the program then there were during the program. This is probably explained by the initial connection date of this site which is close to the start of the promotion program.

Table 4-3, Number of SMEs at CREEs before and after PUE promotion

Name of Community Organization	Connection date	SMEs June 2013	June 2015	Increase
23. Gramin Samudaik Bikas Sanstha	July 2008	15	60	**45 (300%)**
25. Samudaik Sewa Kendra Jilla Samanwaya Samiti	October 2006	20	38	**18 (90%)**
39. Okobara Samudaik Vidyut Upabhokta Samittee	August 2012	21	42	**21 (100%)**
44. Samudaik Urja Bikash Karya Samuha	July 2007	0	57	**57 (n/a)**

4.4 Type of PUEs

4.4.1 Distribution of industry types

Based the description of the businesses given in the monitoring data, they can be classified into the three economic sectors as described by Clark (1940). From the 10 categories of SMEs in Ghana, only agro processing is classified as agricultural industry. Auto body workshop, carpentry furniture, mechanic, other metal work, spare parts and raw materials, welder and wood worker are classified as manufacturing industry. Electrician and food/vendor/amenity/service are classified as service industry. The share of each industry in the total number of enterprises is displayed in Figure 4-13.

In the distribution between the different industry types it is clear that the agricultural industry is lacking and the PUEs consist of mainly manufacturing industry. There is also no clear pattern visible in the development of the different industry types. Instead the distribution seems rather stable. Although, just like in Ghana's economy, manufacturing holds the biggest share, the distribution of industries in the PUE interventions do not represent that of Ghana's economy as displayed in Figure 4-1. Neither does it follow the particular trends in development over time.

The distribution in industry types might be explained by the location where the interventions take place. In the LIZs that are located in the southern part of Ghana there are not many agricultural businesses that could be electrified. It is possible that the agricultural businesses are located in more rural areas where for instance EnDev Ghana program component one and two focus on. When these 250 farmers would be connected to the grid and another 25 are provided with solar irrigation the picture will look a lot differently.

In Indonesia the small shops referred to as “warung”, together with other shops including medical and healthcare services, make up the service industry in PUE interventions. There is one general category of agricultural processing while workshops, manufacturing goods and craft & souvenir making make up the manufacturing industry. The distribution between the different industries is shown in Figure 5-14 for MHP projects and Figure 4-15 for solar power projects.

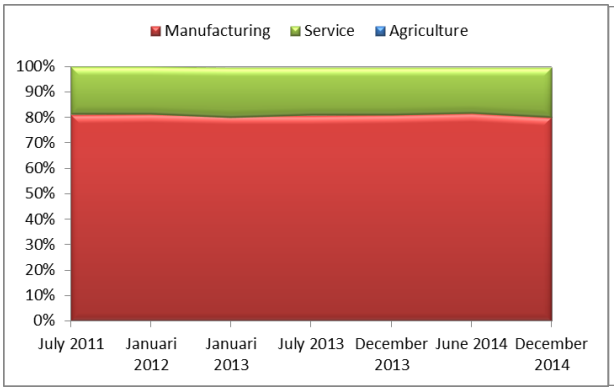

Figure 4-13, Industry types in PUEs Ghana

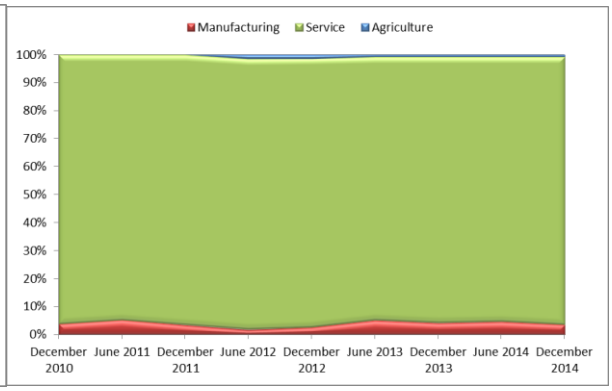

Figure 4-14, Industry types in PUEs Indonesia (MHP)

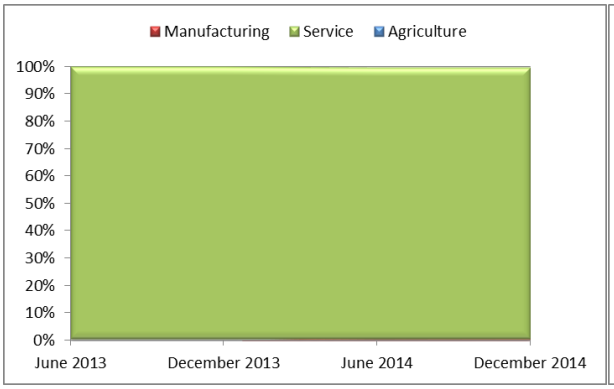

Figure 4-15, Industry types in PUEs Indonesia (Solar)

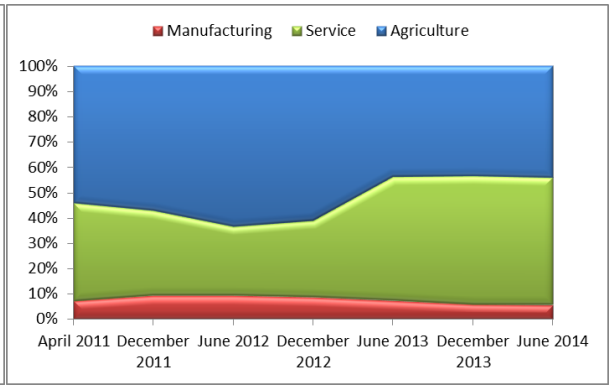

Figure 4-16, Industry types in PUEs Nepal

Almost all PUEs in Indonesia are part of the service industry. Herefore also no trends in the development of other industries can be observed. Although the service industry also holds the largest share in Indonesia’s economy, the distribution of industries in PUEs shows no resemblance with that of Indonesia’s economy displayed in Figure 4-2.

Of all the PUEs in Nepal; poultry farming, rice milling and oil extraction are classified as agricultural industry. Other agricultural activities include irrigation pumps. Shop lighting, communication stations and chilling stations are classified as service industry. Other services include hotels and cell towers. Carpentry shops are classified as manufacturing industry. Other manufacturing includes metal workshops, a block factory and one juice factory. Figure 5-16 shows the percentage each of the 3 industries holds in the total number of PUEs and their development over time.

Overall there seems to be an increase in service industry at the expense of agriculture but there are strong fluctuations over time. Just like in the other two countries there is no clear trend visible. With manufacturing being the smallest and service being the largest industry, the distribution does resemble that of the Nepalese economy displayed in Figure 4-3 in 2011, 2013 and 2014. However in 2012 it doesn’t and this fluctuation isn’t represented in the economy either.

4.4.2 Industry development over time

To track the average development of industries in PUEs over time, the connection dates have to be taken into account. This makes it possible to show the industry composition among PUEs at a certain number of months after initial connection. Figure 4-17 shows this for the PUEs in Ghana and Figure 4-18 that of those in Nepal. For Nepal again only the 25 CREEs shown in Appendix A are included. For Indonesia it was again not possible to analyze the development as there was no data on newly connected SMEs after the initial connection date.

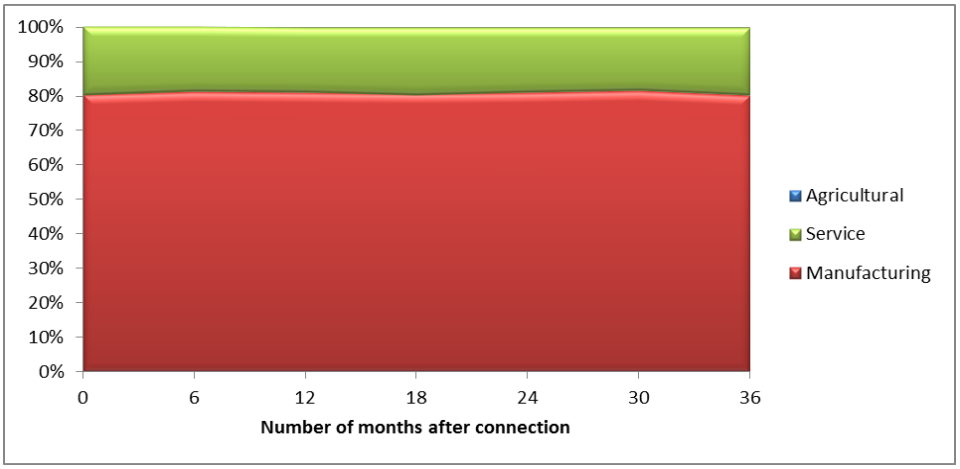

Figure 4-17, PUE industry development over time in Ghana

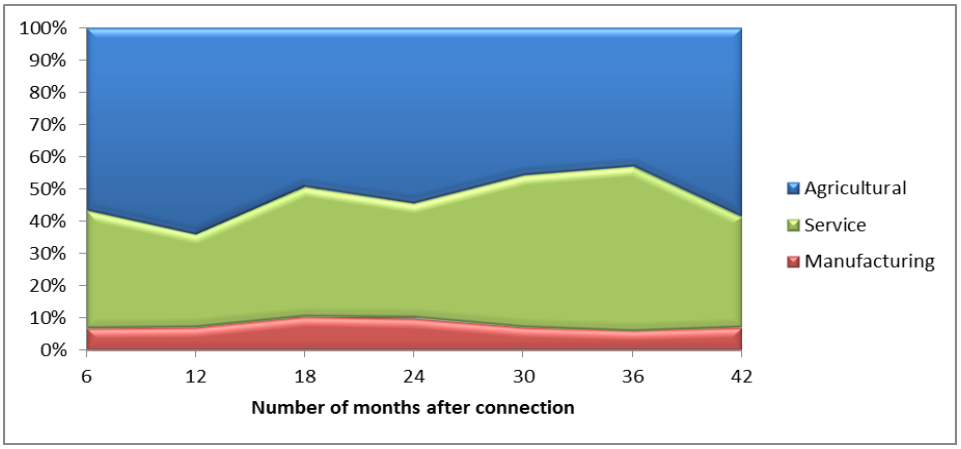

Figure 4-18, PUE industry development over time in Nepal

In Ghana the distribution between industry types in PUEs does not seem to change over time. Immediately after connection around 80% of the PUEs is part of the manufacturing industry and this remains the same for the first three years. This means that also no patterns like described by the model of van Ruijven et al. (2008) can be observed.

In Nepal the largest share of PUEs at the beginning are in the agricultural industry. Although the share of the service industry seems to increase over time, on average agriculture ends up being the largest industry after 42 months. Again the data from Nepal shows a lot of fluctuation, even more so than in Figure 5-16 which did not take into account the different connection dates. Even though the data is based on 25 sites, the model seems susceptible for distortions coming from one single site. This makes the development of industries at CREEs seem rather random and doesn't follow the model of van Ruijven et al. (2008).

5 Conclusion

In answering the question *"In what way do Productive uses of Energy develop over time in electrification interventions?"* it has become clear that countries do not only show differences in relation to each other, but differences also exist within countries. All countries show differences in electricity consumption, grid coverage, electrification rates and economic situation. This means that all electrification interventions take place in their own unique context. The differences in between and within countries are also seen in the amount of SMEs that are connected per site and the type of PUEs that they employ. Despite these differences it is possible to draw several conclusions that hold within the given context of this research.

5.1 Amount of PUEs

The amount of connected SMEs at a site is crucial for the economic viability of a project, and in turn its contribution to sustained economic growth. The promise of generating revenue through PUE opens up possibilities for accessing credit facilities, making electrification interventions less reliant on for instance foreign aid or subsidies. This is reflected in the program in Ghana where no direct EnDev funding is provided but the LIZs are supported in other ways. Also the focus of EnDev Indonesia on the development of relevant sectors through the MSP is evidence of this and although Nepal still provides funding, they also organize PUE workshops.

The results of these efforts are reflected in the amount of PUEs that develop over time at electrified sites. In both the LIZs in Ghana and the CREEs Nepal it can be seen that the average number of PUEs per site, reflected by the number of connected SMEs, increases over time. This leads to conclusion 1a:

Conclusion 1a: *The number of PUEs at a site will increase over time after electrification.*

This means that although the data from Indonesia did not show such an increase yet, the number of SMEs connected per site can here also be expected to increase over time. For future electrification interventions this expected increase can be taken into account in for instance calculating the expected revenue or required capacity. It could also influence the expected impact or economic growth that follows from electrification.

It is also noticed that at the four CREEs in Nepal where PUE was actively promoted in collaboration with Helvetas Swiss and NACEUN, the increase in PUEs was steeper than in the sites without promotion. It is therefore concluded that the promotion program is an effective method for increasing the number of PUEs at a site that has already been electrified. This gives conclusion 1b:

Conclusion 1b: *Active promotion of PUE will increase the number of PUEs at a site faster than it would without promotion*

Because the electrification of LIZs in Ghana and CREEs in Nepal are both grid extension programs it is not possible to determine whether the used technology influences the amount of PUEs. But even though both are grid extension programs, the average number of PUEs in Ghana is higher than that in Nepal. Determining the cause of this difference requires further research.

5.2 Type of PUEs

A shift in industries can be an indicator for economic development (Clark, 1944). To see how electrification is related to economic development, the development of different industries in electrification interventions with PUE was analyzed. From the three countries it can be seen that PUE takes place in all different kinds of businesses. Across the three countries all three industry types are represented. There is however a big difference between the different countries, ranging from the predominantly manufacturing industry in Ghana to the almost completely service orientated industry in Indonesia. An explanation for these differences is sought in the relation to the national economy, economic development theory and possible other contextual factors.

5.2.1 PUEs and the national economy

First an explanation is sought in the differences in the countries their economy. While the economy of Ghana holds a large share of manufacturing industry, the share the manufacturing industry has in the PUEs is much larger. Also the share the agricultural industry holds in Ghana's economy is not represented in the PUEs. The same goes for Indonesia where the share of agriculture and manufacturing industry seen in the economy are not represented in the PUEs. In Nepal the distribution between the different industries in the economy is also not visible in the PUEs. The observations in these three countries lead to the second conclusion.

Conclusion 2: *The composition of industries in PUEs is not related to the composition of industries in a country's economy.*

This means that when planning electrification interventions and predicting what kind of PUEs will establish, predictions cannot be based on the distribution of industries seen in the economy. It is also not likely that changes in the economy will have an effect on what type of PUEs will develop. There are most likely other factors that will determine the types of PUEs that will emerge.

Next to the distribution between industries, it is also possible to look at trends in the development of the economy. Based on this the three economies were classified according to the model of van Ruijven et al. (2008). It could be that that the industries represented in PUE interventions do not hold the same share as they do in the economy, but they do follow its development. This would for instance mean a growing share of manufacturing industry in Ghana, a growing share of service industry in Indonesia and a diminishing share of agricultural industry in Nepal.

This does however not seem to be the case. In all of the countries it is hard to find any pattern at all. In Ghana and Indonesia the distribution between industries is more or less stable and in Nepal there are large fluctuations. This observation leads to the third conclusion.

Conclusion 3: *The development of industry types in PUEs does not follow the development of industry types in a country's economy.*

This means that in predicting future developments of PUEs at electrified sites, the national economy again cannot serve as a reference model. The development of PUEs over time is probably determined by other factors. What these factors are requires further research.

One correlation between the national economy and type of PUEs was observed in two of the three countries. In Ghana where the manufacturing industry is growing, the PUEs are predominantly manufacturing orientated and in Indonesia where the service industry is growing, the PUEs are predominantly service orientated. This could mean that the PUEs make a direct contribution to the developing industries in a country. However in Nepal this does not seem to hold. While on a national level the share of the agricultural industry is diminishing, there is still a large share of agricultural industry in the PUEs. It is here for concluded that there isn't enough evidence for a direct contribution of PUEs to growing industries in the national economy.

5.2.2 PUE and economic development theory

Because the development of different types of PUEs can't be related to the national economy, another way is needed to predict what PUEs will develop over time. It could be possible that the way industries develop around electrified sites is similar to that described in the model of van Ruijven et al. (2008). In order to analyze this, the industry composition at individual sites was tracked for the first few years after a site was electrified.

Just like with the development of the amount of PUEs over time, the data is only available for Ghana and Nepal. In Ghana the distribution between the different industries remains quite stable. Just after connection the largest share of SMEs work in the manufacturing industry and the remainder is part of the service industry. Over the course of three years the distribution stays about the same. Because it is known from conclusion 1 that the number of connected SMEs did increase over time, this means that newly connected SMEs work in the same industry as the ones that were already connected.

The data from Nepal shows large variations in the types of businesses that are connected. These are probably caused by groups of SMEs that are connected at individual sites. The share each industry type holds right after connection is similar to the share they hold 3,5 years after connection. The findings in both countries do not resemble the model as described by van Ruijven et al. (2008) in any way. It is therefore believed that the way industries develop in electrification interventions with PUE is not related to this model. This gives the fourth conclusion.

Conclusion 4: *The development of industry types in PUEs does not follow the traditional model of economic development.*

This means that the type of PUEs that will develop cannot be predicted with the model. It might be that alternative models still have to be developed for this situation or that the industry development does not follow any model and will instead directly follow from the local circumstances. Determining this would require further research.

5.3 Overall conclusion

Overall it became clear that the development of PUEs is most likely determined by local circumstances. No evidence was found for any influence of the distribution of industries in the national economy or the ongoing development of these industries on the development of PUEs. Instead PUEs seem to develop more or less in isolation at individual sites. This also explains the large differences that are observed within countries, especially in Nepal.

This then leads to two additional conclusions. First, electrification interventions have to be designed to fit the local context. Trying to force the development of a specific type of PUE won't work. This means that setting up a single program and implementing it in different parts of a country probably won't result in the highest possible amount of PUEs. This is summarized in conclusion 5.

Conclusion 5: *Each electrification intervention should be individually designed to fit the context of a specific site in order to establish the maximum amount of PUE.*

From this also follows the sixth and final conclusion which is similar but works the other way around. If it is possible to design electrification interventions to fit a specific context, it is also possible to focus electrification efforts on areas where this context exist. This means that if you want to stimulate a specific industry you can focus electrification efforts on areas where these industries will most likely develop. A very direct example of this is the 250 farmers in Ghana that will receive electricity for irrigation. This is a direct stimulation of the agricultural industry but could be applied in any industry that can be electrified. This gives the sixth and final conclusion.

Conclusion 6: *By focusing electrification efforts on specific areas it is possible to stimulate the development of specific industries that are most likely to contribute to economic development.*

This would mean that to support economic growth, it first needs to be identified what industries needs support and the development of which industry is desirable. This then makes it possible to focus electrification efforts on this specific industry.

A final note should be made on the choice of technology for electrification. Although this research set out to try and find how this choice influenced the development of PUEs, the data was not sufficient to make any comparison. It does however seem logical to think that technology choice is one of the design elements as mentioned in conclusion 5. It should therefor always suit the local context in which the electrification intervention takes place.

6 Limitations and future research

Because PUE has only recently become more important in electrification interventions, the available amount of data is limited. Together with Peru, the three chosen countries were the only ones in EnDev with significant PUE experience. Peru was not included because with the available monitoring data it was not possible to see what SMEs where connected and when they were connected. Also from the three selected countries it sometimes took some clarification to determine what was actually established at a site.

A note should also be made about data reliability. By using the raw monitoring data from the countries the data is believed to be more reliable than that represented in external reports. However it should be checked whether this data represents the actual situation. EnDev could clearly benefit from a more uniformly designed monitoring system. This will make data more reliable and will make it easier to transfer knowledge from one country to the next.

The big differences in connected SMEs that were observed in between sites also raise the question whether taking the average number is representative for a country. It could be that specific local circumstances form a bigger determinant than the ones at national level. This could for instance be the social situation, local regulatory framework or a simple matter of convenience. More in depth analysis of individual sites could shed a light on this. However this would make the findings less generalizable.

Another remark on the data concerns the measure used for measuring PUE. Here the number of connected SMEs is used. This means social institutions are not included. Although they generally don't generate revenue, they might contribute to economic development in a broader sense. To determine this would require further research into the effects of social infrastructure on economic development in the given setting. Using the number of SMEs to represent PUE is a first step into understanding economic development. Future studies might want to look at the size of the SMEs, number of employees, energy use and revenue. This would provide a more comprehensive overview of the economic development. In some countries this would however require redesigning the monitoring system.

A final remark is on the analytical framework that was used. This research set out to compare different countries but found that there are large differences within the countries. Because the model describes economic development on a national level it might not be the most suitable to use now it is known that the local context is a strong determinant. There does however not seem to be a suitable model currently in existence.

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8 Appendix

Nepal CREE data availability

Project site	Original connection date	Months after connection: 6	12	18	24	30	36	42
1. Kachal Samudaik Gramin Vidyut Sanstha	September, 2012							
2. Samudaik Vidyut Upabhokta Samiti	August, 2011							
3. Samudaik Gramin Vidyut Upabhokta Samiti	August, 2011							
4. Gramin Samudaik Vidyut Upabhokta Samiti,thapathana	March, 2012							
5. Samudaik Gramin Vidyutikaran Kendra Dubekol khotang	June, 2011							
7. Paiyun Chetra Samudaik Vidyutikaran Upabhokta Samiti	February, 2011							
8. Bahakithati Gramin Samudaik Upabhokta Samiti	January, 2011							
9. Ranipani Gramin Samudaik Vidyut Upabhokta Samiti	May, 2010							
12. Siddhanath Samudaik Gramin Vidyutikaran Sahakari Sanstha Ltd	March, 2013							
15. Maidi Gramin Vidyut Sahakari Sanstha	March, 2010							
16. Gramin Samudaik Adhyan Kendra	March, 2011							
17. Parijat Sahakari Sanstha Ltd.	June, 2009							
21. Ghyampesal Samudaik Bikas Kendra	September, 2010							
22. SanaKisan Sahakari Sanstha Ltd	January, 2011							
23. Gramin Samudaik Bikas Sanstha	July, 2009							
24. Wami Samudaik Gramin	October, 2009							
26. Jana Prakash Samudaik Gramin Vidyut Upabhokta Samitee	June, 2013							
29. Malika Samudaik Vidyut Sahakari Sanstha	August, 2010							
30. Hasfichaur Samudaik Gramin Vidyut Upabhokta Samitee	May, 2011							
33. Palukha Samudaik Gramin Vidyut Upabhokta Samitee	August, 2010							
36. Hugdisir DhulluBaskot Sahakari Gramin Bidyut Upabhokta Samit	November, 2010							
37. Damek Sahakari Gramin Vidyut Upabhokta Samitee	March, 2009							
39. Okobara Samudaik Vidyut Upabhokta Samittee	December, 2008							
41. Gramin Purbadhar Tatha Batabaran Bikas Manch	February, 2009							
43. Shree Adguri VDC Vidyut Upabhokta Samitee	June, 2013							

Data available Data not available